TITLE: Fiber Optic Connector Termination Procedure

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1.0 Introduction

1.1 Objective

The Sea-Con armored “down-hole” electrical / optical hybrid cable used by Earth Sciences for “Single-Well Seismic Imaging” requires periodical maintenance and repair. The cable has both Electrical and Fiber Optic (both single-mode and multimode) communication lines with several interconnections along its length. Tolerance to dirt is near zero in Fiber Optic Connectors. Airborne particles are about the size of the core of “Single Mode” fiber and are usually silica based - they may scratch the end-face of “Physical Contact” connectors if not removed. Fiber Optic transmitters and receivers are extremely susceptible to contamination by particles of dirt or dust, which can obstruct the optical path and cause performance degradation. Test equipment that has fiber-bulkhead outputs also need periodic cleaning, since they may have hundreds of insertions of test cables in short time frames. Good system performance requires clean optics and connector ferrules.

This procedure will describe the preferred method for terminating, inspecting, cleaning, and maintaining the Fiber Optic connectors and Adapters used in the Sea-Con cable assembly.
This procedure will start with some basic information about fiber optic connectors, inspection and cleaning. The remainder will describe the procedures for terminating the connectors unique to the Sea-Con cable.

Note: Due to the custom nature of the Sea Con cable assembly, it is necessary to improvise strain-relief and cable routing solutions as needed in various portions of the cable assembly. This should be done by those familiar with the Sea Con cable assembly. This manual will cover only those issues associated with terminating the fiber optic connectors.

1.2 Assumptions

- Operator should be trained in Basic Fiber Optic handling and safety.
- Operator should be familiar with the Sea-Con cable assembly elements.
- Operator should review standard fiber optic connector termination methods and procedures.
- Operator has practiced standard fiber optic connector terminations with good results prior to attempting fiber optic connector terminations on the custom Sea-Con armored cable.

1.3 Reference

- FOTEC, Inc. (www.FOTEC.com) “Fiber U” training guide.
- Telect, Inc. (www.telect.com) “Connector Characteristics and Their impact on System Performance & Reliability”.
- Newport Corporation (www.newport.com) “Fiber Preparation”
- Fiber Instrument Sales(www.fiberinstrumentsales.com) Tools and Supplies

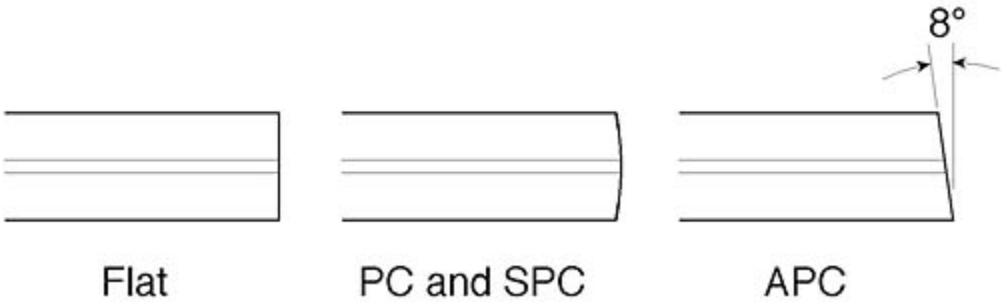
1.4 Definitions, Acronyms, and Abbreviations

Termination - Attaching a connector to the end of a fiber optic cable.

SC/PC - "SC" style connector with Physical Contact (PC) polish that results in a slightly curved connector surface. The fiber ends of mating connector pairs are in physical contact. This eliminates the fiber-to-air interface, resulting in back reflections of –30 to –40dB. The "PC" polish is the common connector endface preparation, used in most applications.

SC/SPC(UPC) - "SC" style connector with Super Physical contact (SPC) or sometimes referred to as Ultra Physical Contact (UPC) polish. In the SPC/UPC polish, an extended polishing cycle enhances the surface quality of the connector, resulting in back reflections of –40 to –50dB. This polish is used in high speed, digital fiber optic transmission systems.

Connector Endface – Three basic styles are used: Flat-non physical contact, PC and SPC – physical contact, and APC- Angled physical contact.



Note: Typical"APC" angle is 8°. Some non-US vendors use 9°, do not attempt to mate an 8°connector with a 9°connector. It is also a good idea to use APC connectors, bulkheads, and adapters from the same vendor to minimize slight angle mismatches.

Jumper - Optical fiber cable that has connectors installed on both ends.

Adapter - A device used to join two like or different fiber optic connectors together. Adapters that join different connectors together are called hybrid adapters.

Ferrule - A mechanical fixture used to align and protect fiber in a connector. Ferrules are typically made of stainless alloy or zirconia.

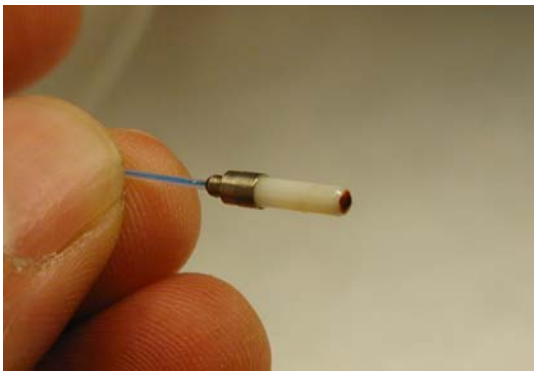
2.0 Procedure Items

- Fiber Optic jumper cables
- Fiber Optic jumper cable connectors
- Fiber Optic connector adapters
- Fiber Optic Equipment Bulkhead adapter connections

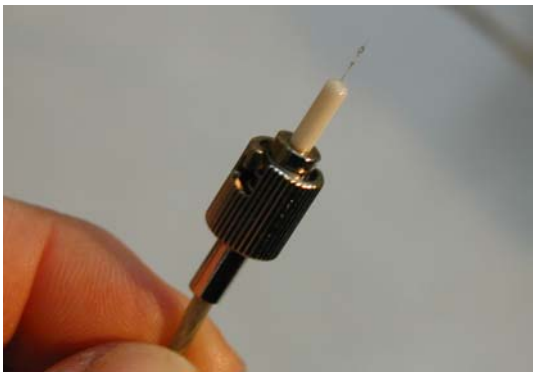
2.1 Connector types:

- Sea Con # 7339-150-05
- Sea Con # 7408-615
- FIS # F1-0066 & F1-0069 St Style F.O. Multimode and Single-mode Connector

Sea Con # 7339-150-05



Sea Con # 7408-615



FIS # F1-0066 & F1-0069 St Style F.O. Multimode and Single-mode Connector

3.0 Item Pass/Fail Criteria

3.1 Ferrules on the connectors/cables used for communication will get dirty by scraping off the material of the alignment sleeve in the connector adapter. Some of these sleeves are molded glass-filled thermoplastic and sold for multimode applications. These will give you a dirty connector ferrule in 10 insertions. You can see the front edge of the connector ferrule getting black. The alignment sleeve will build up an internal ledge and create a gap between the mating ferrules.
Single mode adapters use metallic or ceramic alignment sleeves. We prefer to use adapters with ceramic alignment sleeves. Use only ceramic alignment sleeve bulkheads if you are expecting repeated insertions.

3.2 Inspect the connector end-face for dirt or scratches using a Fiber Inspection Microscope (see figures 3.2.1 & 3.2.2). Pay very close attention to the area of the fiber core in the center of the end-face. Make sure there is no dirt or scratches near the core (see figures 3.2.3 & 3.2.4).
NOTE: Make sure no laser light is present in the fiber when inspecting the end-face. The light in a single mode fiber is highly concentrated at the core and can injure your eye depending on the wavelength and amount of optical power present. Most inspection scope manufacturers have optical safety filters built-in, but it is better to be safe and turn off the laser source.

Figure 3.2.1

Figure 3.2.2

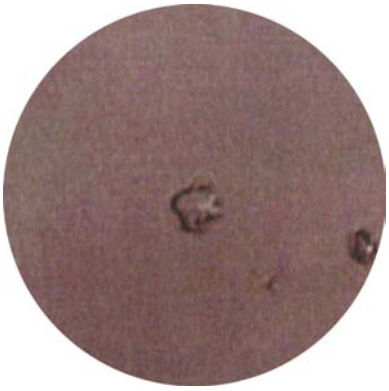


Figure 3.2.3 Dirt on core area.

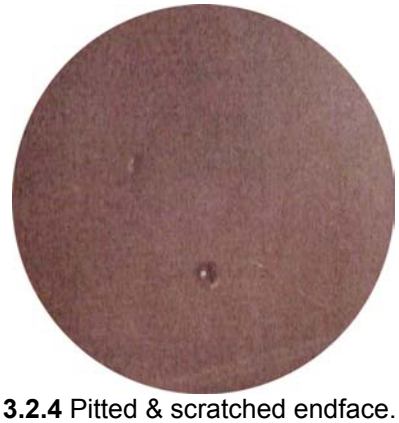


Figure 3.2.4 Pitted & scratched endface.

3.3 The connectors can be used only when the end-faces are free of dirt and/or scratches (See figures 3.3.1 & 3.3.2).

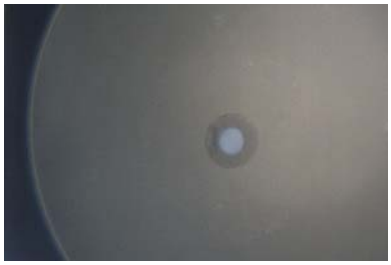


Figure 3.3.1 - Clean End-face

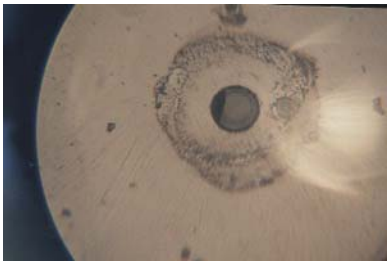


Figure 3.3.2 - Dirty End-face

4.0 Enviromental Needs

4.1 Supplies

- FIS Hand Held Universal Microscope (ST, FC & SC) 100X (FIS P/N F1-9786)
- Non-woven dry wipes 100pk 4"x4" (FIS P/N F1-6702)
- 99% Isopropyl Alcohol (FIS P/N F11007-G) 28oz.
- Alcohol dispensing bottle (FIS P/N F1-007P)
- Cletop Reel Connector Cleaner (FIS P/N F1-6270)
- Replacement tape for Connector Cleaner (FIS P/N F1-6271)
- ST Polish Disc (FIS P/N F1-6295)
- Glass polishing plate (FIS P/N F1-9111A)
- Soft Polish Pad (5" x 5") (FIS P/N 05-00053)
- Lapping Film – 5μm (F1-0109-5), 3μm (F1-0109-3) , 1μm (F1-0109-1), .3μm (F1-0109-03)
- Tra-Con Epoxy (FIS P/N BA-F123)
- 24 Port Connector Heat Oven (FC/ST/D4/SMA/SC) (FIS P/N F1-9772)
- Syringe w/ 1.2mm needle (FIS P/N 501473-3IR)
- Black shrink tubing w/adhesive – 3/32”, 1/8”, 3/16”, 1/4" x 6”
- Heat Gun (LBL Stores)
- Teflon tubing – 26AWG
  Note: It is a good idea to have an assortment of sizes up to ¼” O.D.
- Canned air (FIS P/N F1-1007)
- Fiber Disposal Unit (FIS P/N F1-8328)

4.2 Tools

- Standard scissors
- Kevlar scissors (FIS P/N F16430)
- Tweezers (General use, strong blades w/ fine points, Anti-magnetic, 4 ¾” OAL)
- Miller Stripper (FIS P/N WO-1224) and Clauss striper (FIS P/N W O-1225)
- “IDEAL” jacket cutting tool #45-163 (FIS P/N F1-0021)
- Sharp wire cutters “Xcelite” #170M
- “Sharpie” felt tip markers
- Ruby (FIS P/N 3233304-01) or Carbide(FIS P/N F1-9773) fiber optic cleaving tool.

- "Crimplok" tool # 6955C set @ .137"

5.0 Staffing and Training Needs

5.1 Staffing

- 2 – trained technicians

5.2 Training

- Review videos: "A hands On Look at Fiber Optics" (Fiber Instrument Sales)
  "Introduction to Fiber Optic Theory and Fiber Structure"
  (The Light Brigade)
  "Amp Fiber Optic Connectorization"

6.0 Responsibilities

- The Operator is responsible for following and performing all procedures described in this document.
- The Operator will complete LBNL "Laser Safety Training" prior to performing any of the procedures described in this document.

7.0 Procedures and Recommendations

7.1 General precautions

7.1.1 Always keep dust caps on unused connectors, bulkhead splices, patch panels or anything else that is going to have an optical connection made with it. Store spare caps in a dust free environment such as a sealed plastic bag or box so that when reinstalled they do not reintroduce any contamination to the optics (See figures 7.1.1.1 & 7.1.1.2).

Figure 7.1.1.1 SC/SPC w/Dust Cap

Figure 7.1.1.2 Replace Dust Cap

7.1.2 Always clean the connector prior to insertion into an adapter or bulkhead (even if it is brand new) using a tape and reel cleaner cartridge (see figure 7.1.2.1).

NOTE: Make sure no laser light is present in the fiber when cleaning the end-face. The light in a single mode fiber is highly concentrated at the core and can actually burn the cleaning material depending on the amount of optical power present. This can contaminate the fiber end-face.

Figure 7.1.2.1 Connector cleaning (standard practice for most connectors)

7.1.3 Ensure that the end-face of the connector does not come into direct contact with any surface other than the mating connector or approved cleaning materials prior to insertion into an adapter or bulkhead (see figure 7.1.3.1).

Figure 7.1.3.1 SC/APC Plug-in

Figure 7.1.3.2 FC/SPC Plug-in

7.1.4 Do not bend an optical fiber or cable at a radius less than 25mm (50mm diameter). Fiber is made from glass and can weaken or break when the specified bend radius is exceeded. Also, when optical fiber is bent, light begins to leak out of the fiber core. This affects the insertion loss of the cable and can affect optical performance and test results (Figure 7.1.4.1 & 7.1.4.2)

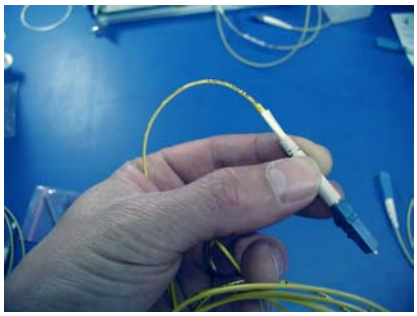


Figure 7.1.4.1 Radius is acceptable.

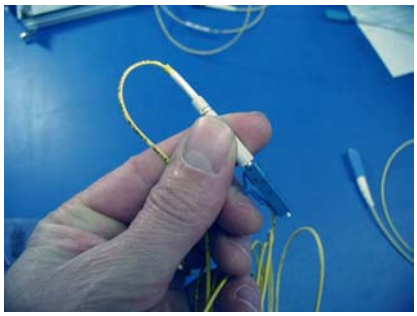


Figure 7.1.4.2 Radius is not acceptable.

7.1.5 Always hold optical cables by the connector, never by the cable with the connector dangling.

7.1.6 Remember that fiber optic cable and connectors are very expensive. Sea Con connectors start at $75.00 each.

7.1.7 Be careful not to crush or kink optical fiber cables. Inspect the length of the cable for tight bends, kinks, or evidence of being crushed or pinched. Discard any cables that have been damaged (see figures 7.1.7.1 & 7.1.7.2)

Figure 7.1.7.1 Cables can be damaged or crushed by equipment resting on it.

Figure 7.1.7.2 Discard damaged cables.

7.2 Cleaning Procedure

7.2.1 Use only a tape and reel cleaner cartridge, fiber optic swab, lint free pad, or lens paper wetted with filtered 99% isopropyl alcohol to clean the connectors. Some solvents might attack epoxy, so only alcohol should be used. Cotton swabs and cloth leave threads behind. Some optical cleaners leave residues. Residues usually attract dirt and make it stick.

7.2.2 Start with the optical test equipment. The optical interface bulkheads can be cleaned with precision fiber optic swabs that are inserted into the bulkhead.
The Sea Con and ST bulkheads use a 2.5mm foam swab. Blow out the bulkhead with canned air designed for use in fiber optics (see figures 7.2.2.1 & 7.2.2.2)

Figure 7.2.2.1 Fiber Optic Swabs

Figure 7.2.2.2 Canned air

7.2.3 Connector End-face

7.2.4 If the routine cleaning method described in section 7.1.2 does not sufficiently clean the connector end-face, clean the end-face as follows:

1.) Wet a folded piece of lens paper w/ 99% IPA and place flat on a clean bench top or work area (see figure 7.2.4.1)

Figure 7.2.4.1

2.) Rub the end-face on the wetted lens paper in a figure 8 motion. Follow this step by cleaning the end-face with a tape and reel cleaner cartridge. (see figures 7.2.4.2 & 7.2.4.3)

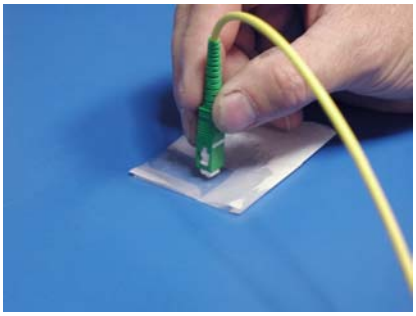


Figure 7.2.4.2

Figure 7.2.4.3

7.2.5 Re-inspect the end-face as described in section 3.2 and repeat if necessary. Discard the connector and re-terminate if cleaning does not result in an acceptable end-face.

8.0 Connector Termination

8.1 The termination procedure itself is common to the four types of connectors used in the Sea Con cable. The process is the same for both single-mode and multimode fiber. Each termination should be planned out and all parts such as heat shrink tubing, springs, O-Rings, clips etc. should be in place and the cable routed though any cable heads and/or adapters. It is very frustrating to find a forgotten part or that the connector cannot be placed after being terminated! The other thing to remember is to maximize the slack cable in case the connector needs to be replaced. Always try to allow for 2 additional terminations.

8.2 Sea Con 7339-150-16 connector to 900μm Teflon tubing.

1.) Strip 15.25mm of Teflon tubing and buffer to expose bare fiber (see figure 8.2.1)

Figure 8.2.1

2.) Clean fiber with IPA soaked Kim-Wipe (see figure 8.2.2)

Figure 8.2.2

3.) Prepare BA-123 epoxy (see figure 8.2.3), mix well (see figure 8.2.4), place in 3ml syringe (see figure 8.2.5), work out trapped air and place 1.2mm needle on end.

Figure 8.2.3

Figure 8.2.4

Figure 8.2.5

4.) Inject epoxy into connector (see figure 8.2.7). Inject only until a small dot of epoxy protrudes from the tip (see figure 8.2.8).

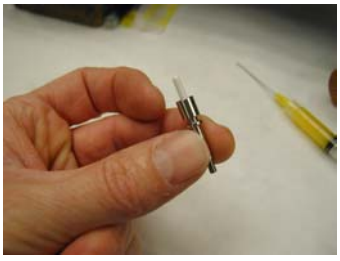


Figure 8.2.6

Figure 8.2.7

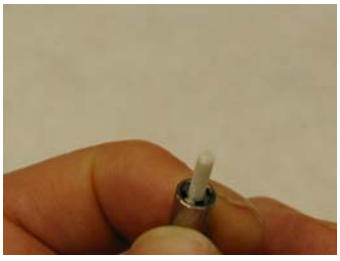


Figure 8.2.8

5.) Carefully and slowly slide the fiber into the connector. Be very careful not to break the bare fiber inside the connector. The fiber should protrude about 5mm from the end of the ferrule. The 900μm Teflon tubing will have stopped inside the connector and a small amount of epoxy should form a "fillet" between the O.D. of the Teflon tubing and the I.D. of the back of the connector (see figure 8.2.9).

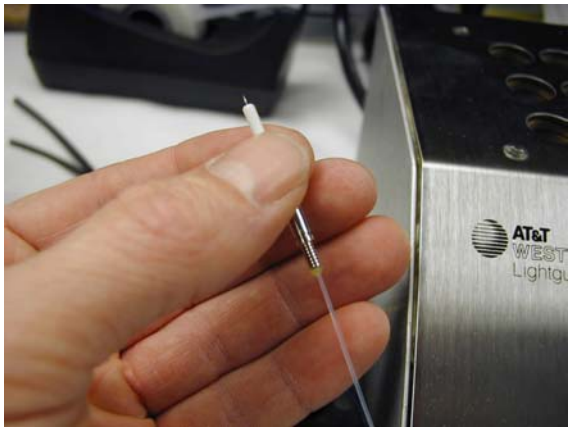


Figure 8.2.9

6.) Carefully place the connector in the curing oven. Make sure to use the custom insert to hold the connector vertical (see figure 8.2.10). Make sure that the fiber does not protrude beyond the end of the insert. Place the insert and connector into the curing oven for 10 – 15 minutes (see figure 8.2.11). The epoxy will turn to an amber color when cured (see figure 8.2.12).

Figure 8.2.10

Figure 8.2.11

Figure 8.2.12

7.) Carefully cleave the fiber close to the cured epoxy on the end of the ferrule. This is done by making a small "scratch" on the glass fiber just above the epoxy, then pulling the extra fiber strait away from the end of the ferrule. Do NOT bend the fiber to break it! This could cause a crack to propagate down into the connector. This is a critical step. The fiber must not shatter down inside the connector. The cleaving will assure a clean break, and the extra epoxy will support the glass fiber during polishing. Some procedures advise no extra epoxy at the tip. This is only to speed up the process. The extra epoxy adds time to the polishing process, but reduces the chance of shattering the glass fiber inside the connector during polishing (see figure 8.2.13).

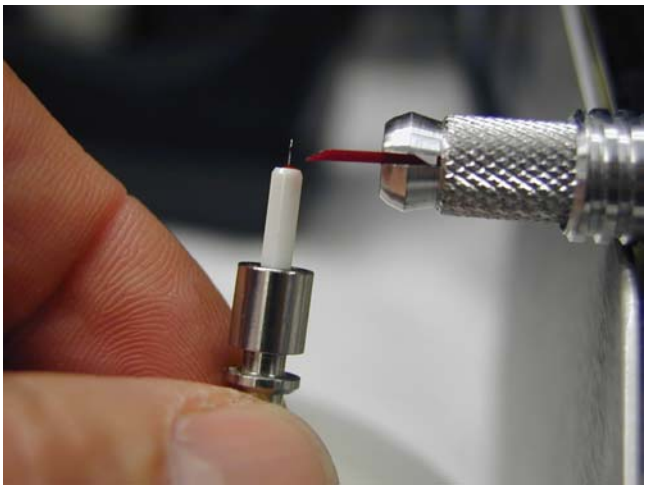


Figure 8.2.13

8.) Lightly swipe the tip of the fiber on a small piece of 5μm lapping film held between the fingers to remove any shards or protruding edges (see figure 8.2.14).

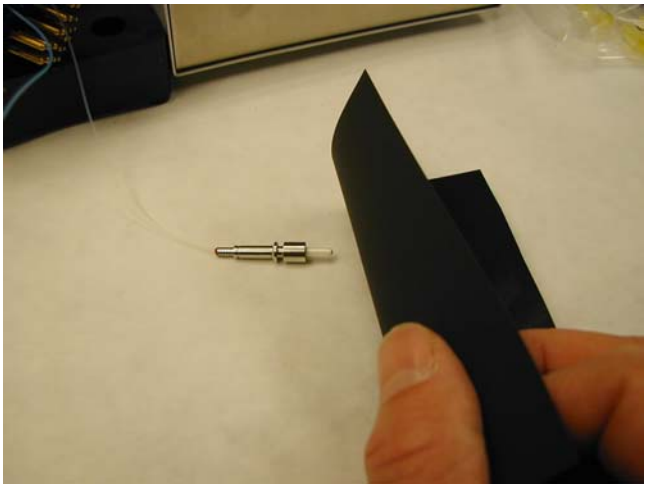


Figure 8.2.14

9.) Clean the glass polishing plate and disk with IPA and Kim-Wipe. Place a 3x4" piece of 5μm lapping film onto the plate. Make sure there is no dust or particles trapped between the lapping film and the glass plate.

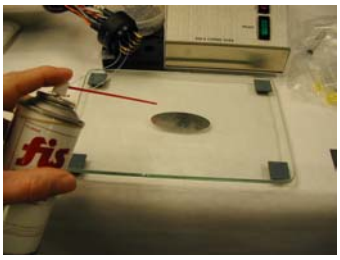


Figure 8.2.15

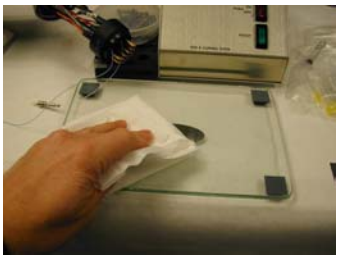


Figure 8.2.16

Figure 8.2.17

10.) Place the connector in the polishing disk. Make sure that the connector ferrule slides easily into the disk – it must be able to "float" during polishing. Sometimes a small bit of epoxy can be on the side of the ferrule. Use a new razor blade and lightly scrape away any epoxy. Clean the ferrule with an IPA soaked kimWipe and try again to place the connector into the polishing disk (see figure 8.2.18).

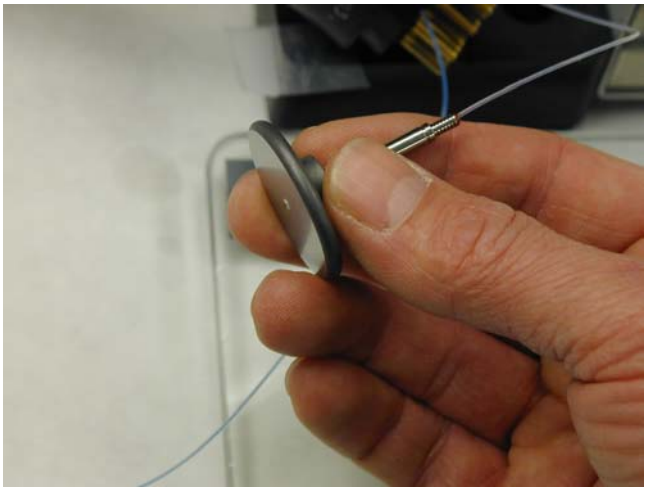


Figure 8.2.18

11.) Lightly polish the connector in "figure 8" motions 8 to 10 times (see figure 8.2.19). Inspect the tip with the FIS Hand Held Universal Microscope. The epoxy should be flat just beyond the O.D. of the glass fiber. Discard the 5μm lapping film and place a new 3x4" piece of 3μm lapping film onto the plate. Make sure to clean the glass polishing plate and disk with IPA and Kim-Wipe every time the lapping film is replaced.

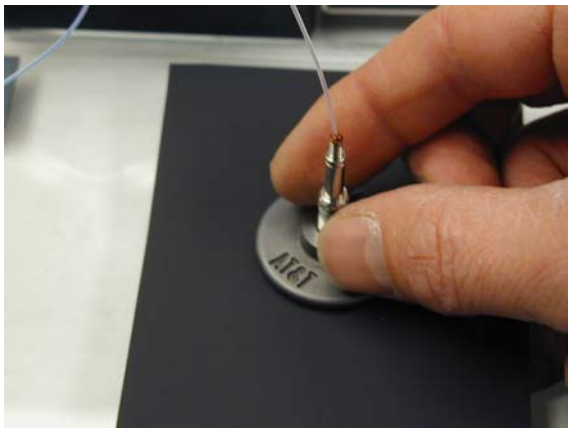


Figure 8.2.19

12.) Continue polishing in "figure 8" motions 10 to 15 times per sheet of 3μm lapping film.
Remember to inspect the tip and clean the plate and disk between each sheet of film. The film "loads" quickly because of the epoxy. It is very important to change the film often. Epoxy can build up and contribute to pitting the glass end-face of the fiber. These pits are very hard if not impossible to polish out and can ruin your hard work! It will seem like you are using a lot of paper at first, but as you gain experience you will use less material.

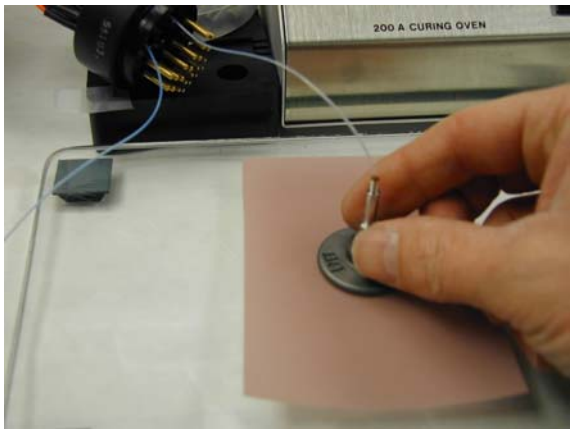


Figure 8.2.20

13.) Continue until a thin film of epoxy is still on the connector (see figure 8.2.21). This can take 3 to 6 sheets of film. Make sure that the fiber end-face is not pitted. If it begins to look pitted, change to 1μm lapping film and continue polishing.

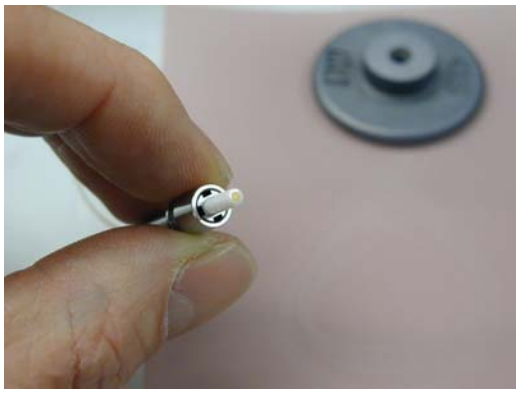


Figure 8.2.21

14.) Change to 1μm lapping film and continue the process until the end-face is clean and polished.

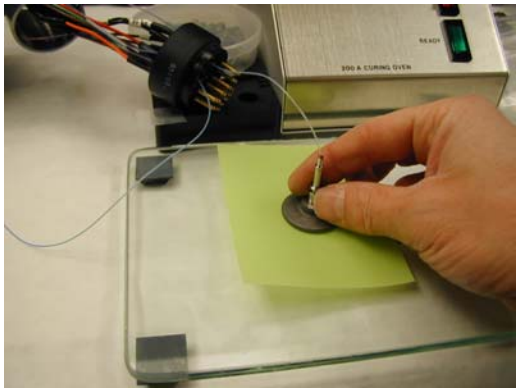


Figure 8.2.22

15.) Change to 0.3μm lapping film. Finish with 8 to 10 “figure 8s”. Inspect the end-face and place a dust cap on the end of the connector. Any O-Rings, springs, heat shrink tubing etc… can now be placed on the connector.

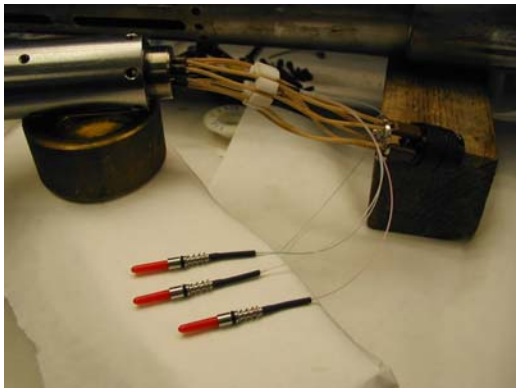


Figure 8.2.23

8.3 FIS Single-mode ST connector #F1 - 0069 to Sea Con Armored cable.

1.) Make a mark 25mm from the end of the armored cable (see figure 8.3.1).

Figure 8.3.1

2.) Using the jacket cutting tool. Make a cut in the jacket down to the steel braid at the 25mm mark.

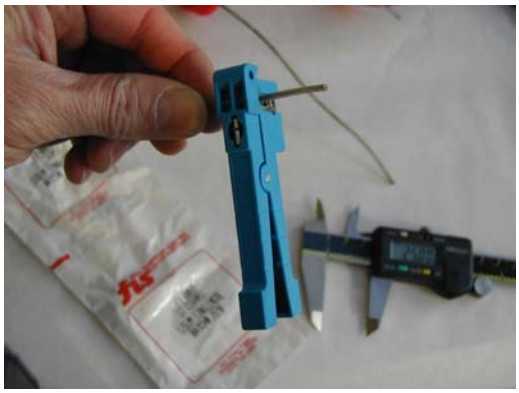


Figure 8.3.2

3.) Carefully make a cut along the side of the jacket with a sharp razor blade from the 25mm mark to the tip of the cable (see figure 8.3.3). Remove the jacket to expose the steel braid (see figure 8.3.4).

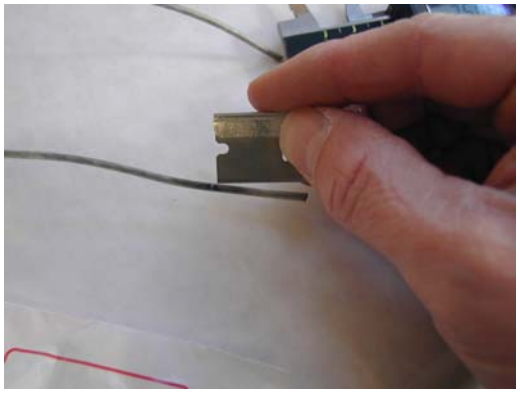


Figure 8.3.3

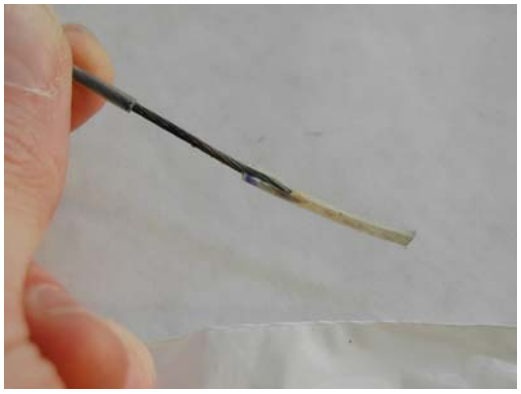


Figure 8.3.4

4.) Gently twist the steel braid to expose the 900μm tight jacket on the fiber (see figure 8.3.5). Fan-out each strand in a radial pattern and make a slight bend on each stand back against the armored portion of the cable (see figure 8.3.6).

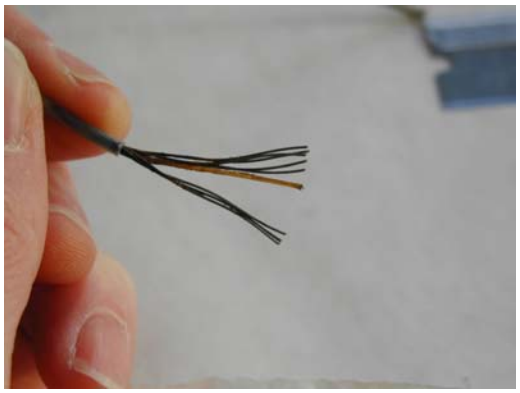


Figure 8.3.5

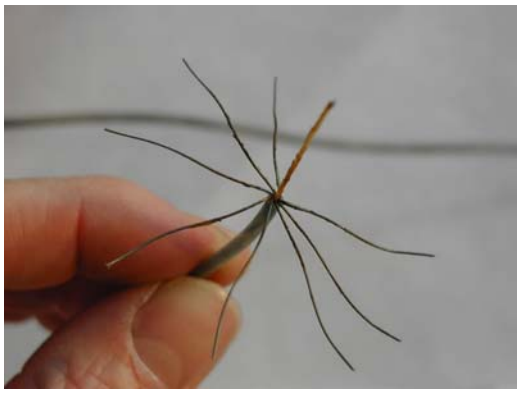


Figure 8.3.6

5.) Using a sharp wire cutter such as the “Xcelit #170M, carefully cut each wire as close a possible to the edge of the armored portion of the cable (see figure 8.3.7). Be careful not to nick or cut the buffered fiber. Clean the fiber jacket with an IPA soaked pad (see figure 8.3.9).

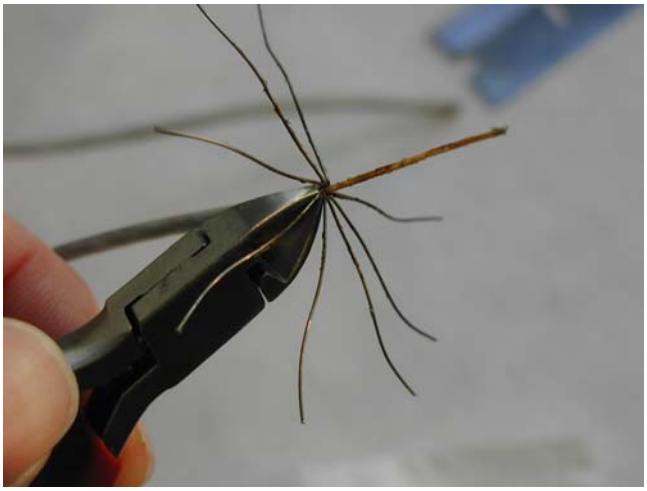


Figure 8.3.7

Figure 8.3.8

Figure 8.3.9

6.) Make a mark 16mm from the tip of the fiber and strip the buffer to expose the bare fiber (see figure 8.3.10). Use the Miller Stripping tool to remove the jacket in 1/8” bits until the 16mm mark (see figure 8.3.11). This should leave about 9mm of jacket left. Clean the bare fiber with an IPA soaked pad.

Figure 8.3.10

Figure 8.3.11

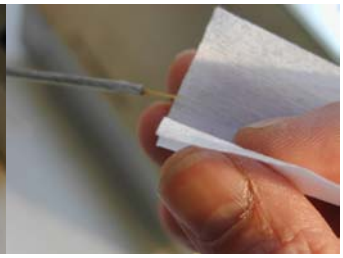


Figure 8.3.12

7.) Epoxy, cure, and polish the connector as described in section 8.2.

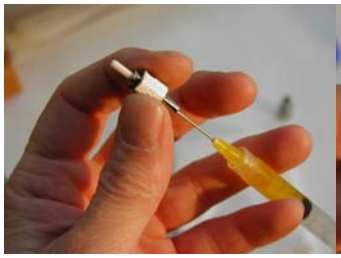


Figure 8.3.13

Figure 8.3.14

Figure 8.3.15

Figure 8.3.16

Figure 8.3.17

Figure 8.3.18

8.4 Sea Con 7339-150-16 connector 3.0mm Kevlar reinforced MM or SM cable.

1.) This termination requires the use of a Sea Con Crimp ring # 7182-291 and heat shrink tubing in addition to the Sea Con 7339-150-16 connector.
Note: Single-mode cable is typically yellow and Multimode cable is orange. The termination procedure is the same.

2.) Slide on a 1/4" O.D. x 1.0" long piece of black adhesive shrink tube over the end of the 3.0mm cable. Next, slide the Sea Con crimp ring over the cable end (see figure 8.4.1).

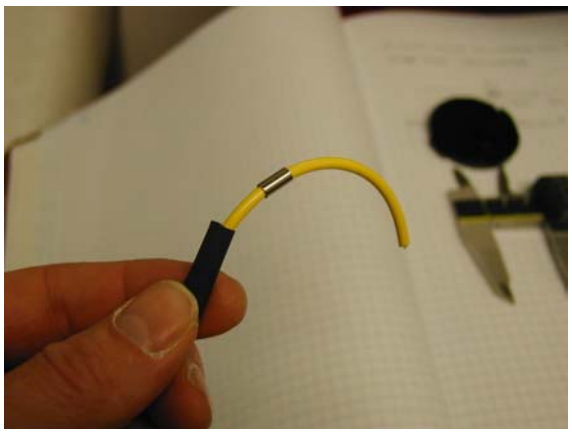


Figure 8.4.1

3.) Make a mark 40mm from the end of the cable.

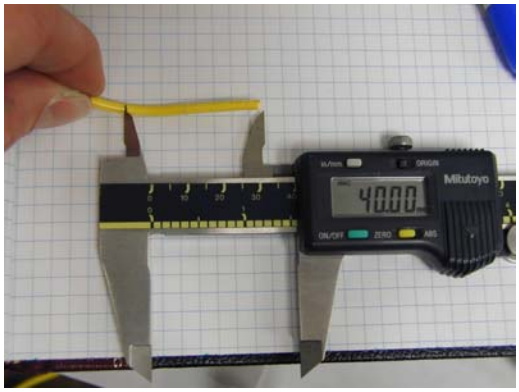


Figure 8.4.2

4.) Strip the outer jacket at the 40mm mark with the “Clauss” striper to expose the Kevlar reinforcement layer. Trim the Kevlar to within 5mm of the outer jacket (see figure 8.4.3).

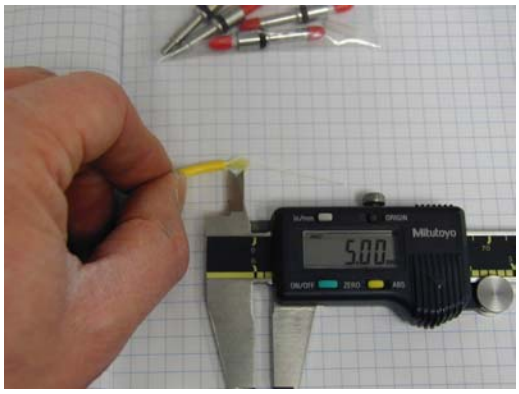


Figure 8.4.3

5.) Make a mark on the 900μm tight jacket 15mm from the end of the fiber. Use the Miller Stripping tool to remove the jacket in 1/8” bits until the 15mm mark.

Figure 8.4.4

6.) Clean the fiber, fill connector with epoxy and slide fiber into the connector until the back of the connector touches the edge of the yellow or orange outer jacket. Fan out the Kevlar and slide the crimp ring over the Kevlar so it is trapped between the O.D. of the back of the connector and the I.D. of the crimp ring. Make sure that the fiber cable is still fully inserted into the connector and crimp the ring to the body of the connector using the "crimplok" tool # 6955C in the .137" position.
Note: Disregard the red fiber cap in the photo, it will not be in place at this time due to the un-cured fiber that protrudes from the end.

Figure 8.4.5

7.) Cure, cleave, and polish the connector as described in section 8.2.

8.5 Sea Con 7408-615 connector to 900μn loose tube.

1.) Study Sea Con drawing # 7408-152 "Modified ST connection Asembly". Make sure that all of the various parts are in place on both ends before terminating the # 7408-615 Ferrule Sub-Assembly.

2.) Make a mark on the 900μn loose tube 15.25mm from the end of the fiber.

Figure 8.5.1

3.) Clean the fiber, fill the connector with epoxy and place the fiber into the connector until it stops. There should be about 5mm of fiber protruding from the end of the ferrule. Slide an FIS # F1-8300CS Zirconia split sleeve over the ferrule end to protect the un-cured fiber protruding from the end of the ferrule (see figure 8.5.2). This will allow the small custom connector to be placed into the curring oven while protecting the tip of the bare fiber protruding from the end. MAKE ABSOLUTELY SURE THAT NO EXCESS EPOXY FROM THE TIP OF THE FERRULE GETS ON THE SPLIT SLEEVE! THIS WILL EPOXY THE SLEEVE TO THE FERRULE. The split sleeve must be removed without braking the fiber after the curing process (see figure 8.5.3).

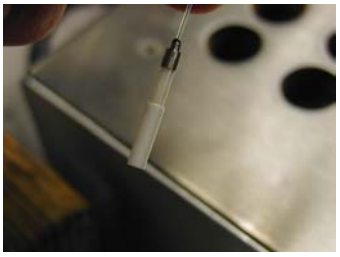


Figure 8.5.2

Figure 8.5.3

Figure 8.5.4

4.) Cure, cleave and polish the connector as described in section 8.2.

9.0 Summary

9.1 Use care when working with any optical transmission equipment. It is good practice to avoid looking directly at any optical fibers or optical sources. Always refer to the company safety procedures when working with optical systems.
It is important to keep all optical connections and surfaces free from dirt, oils or other contamination to ensure proper operation. Scratched or contaminated connectors can reduce performance. Always replace protective dust caps where available.
Always inspect cable ends before use, even if they are brand new. Inspect optical equipment cabling often and clean or replace if necessary.